CLEANROOM ENERGY BENCHMARKING SITE REPORT

FACILITY K

NORTHERN CALIFORNIA

JANUARY 2005

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LAWRENCE BERKELEY NATIONAL LABORATORY

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I. INTRODUCTION

As part of the California Energy Commission Public Interest Energy Research (PIER) project, energy use at Facility K was monitored November 15 to November 24, 2004. The project is administered by LBNL (Lawrence Berkeley National Laboratory) and funded through the California Energy Commission.

This site report reviews the data collected by the monitoring team and presents a set of performance metrics as well as a complete set of trended data points for energy end uses for equipment supporting and located in the cleanrooms. In addition, the energy end uses for equipment supporting and located in a non-clean lab area were monitored. Energy metrics were established that allow facility owners to evaluate their energy efficiency performance and identify opportunities for improvements that reduce their overall operating costs.

First, the report reviews the site characteristics, noting design features of the cleanrooms and lab area monitored. Second, the energy use for the cleanrooms and lab area is broken down into components. Third, performance metrics recorded through the project are presented. Finally, key energy efficiency observations for the facility are noted. This is not intended to be a full energy audit, merely observations from the site measurement team. The data collected, trended graphs and methodology documentation are included among the appendices.

II. REVIEW OF SITE CHARACTERISTICS

A. Site

Facility K, built in 2001, is a single-story facility located in Northern California, which provides services to the electronics industry. The facility consists primarily of office spaces, two lab areas, and cleanrooms. The facility is a total of 22,600 square feet (sf). The total square footage of the cleanrooms is 1,821 sf. One lab area is 4,645 sf and the other lab area is 1,684 sf. The 4,645 sf lab area was monitored in this study. The remainder of the building (14,450 sf) is made up of office spaces, conference rooms, a lunch area, a shipping and receiving area, bathrooms, and other miscellaneous rooms.

The cleanrooms and one of the lab areas were selected for this study. The air systems, process equipment, and lighting were monitored. The environmental systems serving the cleanrooms and lab area run 8,760 hours a year in order to maintain conditions and provide a safe environment.

B. Cleanrooms

The cleanrooms are made up of one ISO class 4 (class 10) area, two ISO class 5 (class 100) areas, two ISO class 7 (class 10,000) areas, and a non-classified gowning room. Airflow is cascaded from the highest cleanliness to the lowest. The following table summarizes the areas of each cleanroom. The primary area is the certified rated area of the cleanroom. The secondary area is the area where the air is returned to the air handling units.

Table 1. Cleanroom Areas

Cleanroom	ISO Class	Primary Area (sf)	Secondary Area (sf)	Total Area (sf)
136 – Gowning	Not rated	99	18	117
137	7	608	52	660
138 – Inter-gowning	5	72	0	72
139	4	170	12	182
140	7	367	54	421
141	5	334	35	369
Total	N/A	1,650	171	1,821

The cleanrooms are conditioned by a rooftop package unit, AC-5, which provides both makeup air and recirculation air. The air handler supplies air to an interstitial space and then to fan filtered HEPA units (FFUs) located in the ceiling, which provide the recirculation air to the cleanroom. The air is returned via a low-sidewall return. There are four fume hoods located in the cleanrooms with each having its own exhaust fan. There is also a general exhaust fan for heat removal, which is directly connected to various equipment located in the cleanrooms.

In addition to measuring the air handling systems for these areas, measurements were taken on the power consumption of the process equipment located in the cleanrooms as well as the lighting power consumption.

C. Lab Area

The lab area is conditioned by two identical rooftop package units, AC-2 and AC-3, which both provide makeup air and recirculation air. For the purpose of this study, the package units are considered as makeup air handlers. Both air handlers are ducted to attempt an even supply of air into the lab area. There are five fume hoods located in the lab area with each having its own exhaust fan. There is also a general exhaust fan for heat removal, which is directly connected by ducts to the various equipment located in the cleanrooms. Although the facility is unoccupied at night, the systems run 24 hours a day since some experiments require more than a day to complete.

Measurements were taken on the power consumption of the process equipment and lighting in addition to the power use of the air handling systems.

III. SITE ENERGY USE CHARACTERISTICS

A. Cleanroom & Lab Area Power Consumption

The energy consumption attributed to the cleanroom is shown in the table and pie chart below. This information will help for comparisons of different cleanroom air handling system efficiencies.

Table 2. Cleanroom Power Consumption

Description	Average Load (kW)	Average Efficiency
AIR HANDLING		
Makeup Fan	6.5	1,443 cfm/kW
Recirculation Fans [1]	8.3	3,503 cfm/kW
EXHAUST FANS [2]		
EF-6 (Fume hood)	0.50	-
EF-7 (Fume hood)	0.68	-
EF-8 (Fume hood)	0.60	-
EF-9 (Fume hood)	0.49	-
EF-10 (General exhaust)	2.4	-
PROCESS POWER	18.7	11.3 W/sf
LIGHTS	3.2	2.0 W/sf
TOTAL	41.4	-

1. *Air handler, AC-5 provides both makeup and recirculation air; the fan power attributed to the recirculation air was 3.2 kW. The FFU power consumption was measured at 5.1 kW.*
2. *An efficiency for the exhaust fans could not be determined since airflow data was not available.*

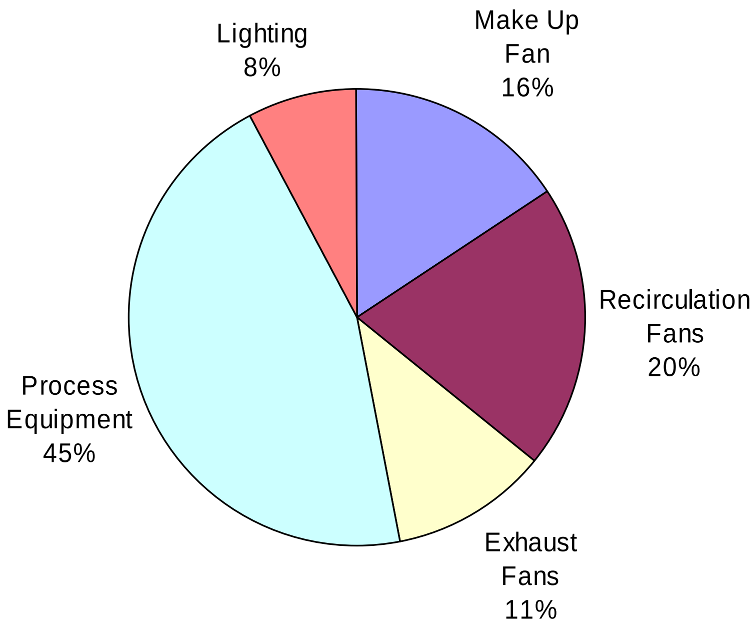
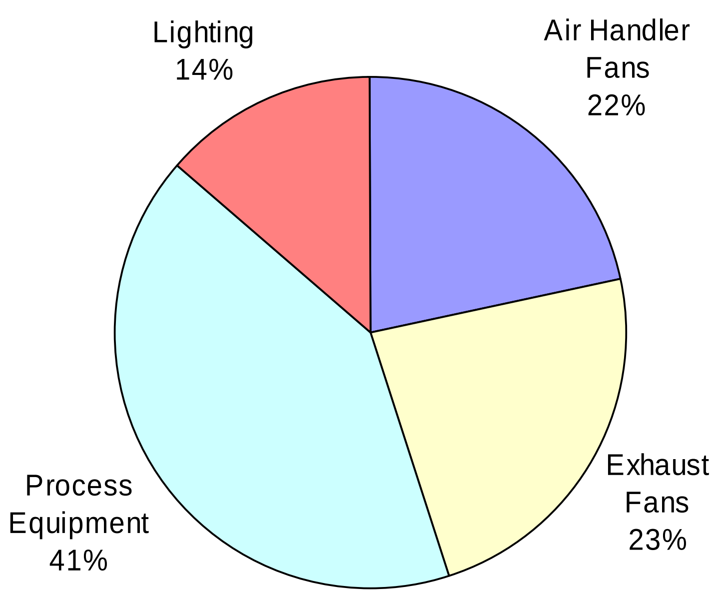


Table 3. Lab Area Power Consumption

Description	Average Load (kW)	Average Efficiency
AIR HANDLING		
AC-2 Supply Air Fan [1]	1.91	3,139 cfm/kW
AC-3 Supply Air Fan [1]	2.02	2,976 cfm/kW
EXHAUST FANS [2]		
EF-3 (Fume hood)	0.97	-
EF-4 (Fume hood)	0.89	-
EF-5 (Fume hood)	0.44	-
EF-11 (General exhaust)	1.5	-
EF-12 (Fume hood)	0.43	-
PROCESS POWER [3]	7.5	1.6 W/sf
LIGHTS	2.4	0.52 W/sf
TOTAL	18.0	-

1. *The air handlers provides both ventilation and recirculation air.*
2. *An efficiency for the exhaust fans could not be determined since airflow data was not available.*
3. *Spot measurements were taken only for the process equipment.*



IV. SYSTEM PERFORMANCE METRICS

Metrics are ratios of important performance parameters that can characterize the effectiveness of a system or component. In order to gage the efficiency of the entire building system design and operation, this project tracks key metrics at different system levels. These metrics can be used to compare designs or determine areas with the most potential for improvement via retrofit or replacement.

For Facility K, the cleanroom HVAC components operate at a nearly constant level throughout the year. Therefore, these metrics are based on spot measurements, and various logged data to ensure accuracy. All of the metrics involving area are based on the primary cleanroom area, which is the area that passes certification, unless otherwise noted.

Table 4. Cleanroom Metrics

Description		
MAKEUP AIR HANDLING		
Makeup Airflow	cfm	9,445
Makeup Air Fan Power	kW	6.5
Makeup Air Efficiency	cfm/kW	1,443
Makeup Air	cfm/sf	8.5
Makeup Air Fan Power Density [1]	W/sf	5.9
RECIRCULATION AIR HANDLING		
Recirculation Airflow	cfm	28,908
Recirculation Air Fan Power	kW	8.3
Recirculation Air Efficiency	cfm/kW	3,503
Average Filter Face Velocity	fpm	57
Recirculation Air Fan Power Density [1]	W/sf	5.0

1. *Calculated as total kW load divided by the primary area of the cleanroom.*

Table 5. Cleanroom Airflow Rates

Description		***Room 139 ISO Class 4***	***Room 138 ISO Class 5***	***Room 141 ISO Class 5***	***Room 137 ISO Class 7***	***Room 140 ISO Class 7***	***Room 136 (unrated)***
Recirculation Airflow	cfm	8,712	2,712	14,027	3,744	3,733	375
Air Change Rate	ACH	342	251	280	41	69	25
Recirculation Air	cfm/sf	51	38	42	6	10	4
Average Filter Face Velocity	fpm	69	45	63	61	36	49

Figures 1 and 2 on the following pages compare the recirculation and makeup air handling systems benchmarked in this study. The fan filter unit recirculation air handling system for this facility is more efficient than what was benchmarked at most other facilities. This is due to the low operating ranges of face velocities for the fan filter units. The operating face velocities of the FFUs ranged between 36 to 69 fpm. The FFU face velocity measured in Facilities B.1 and B.2 was both 76 fpm, and 61 fpm in Facility E. The average FFU face velocity for this facility was 57 fpm. Lower face velocities result in lower pressure drop (or resistance) of the air moving across the filter. This equates to lower fan power consumption to circulate the air through the unit.

Figures 3 and 4 compare the air change rates of the one ISO class 4 (class 10) and the two ISO class 5 (class 100) cleanrooms to other cleanrooms of similar class at the different facilities benchmarked. The ISO class 4 cleanroom air change rate is the lowest of the six facilities as shown in Figure 3. This shows that cleanliness in a cleanroom can still be maintained at lower amounts of airflow. In Figure 4, the cleanrooms at this facility are operating close to the average air change rate of all of the cleanrooms. An opportunity for energy savings is to turn down of the recirculation airflow for these two cleanrooms (also see *Site Observations Regarding Energy Efficiency*).

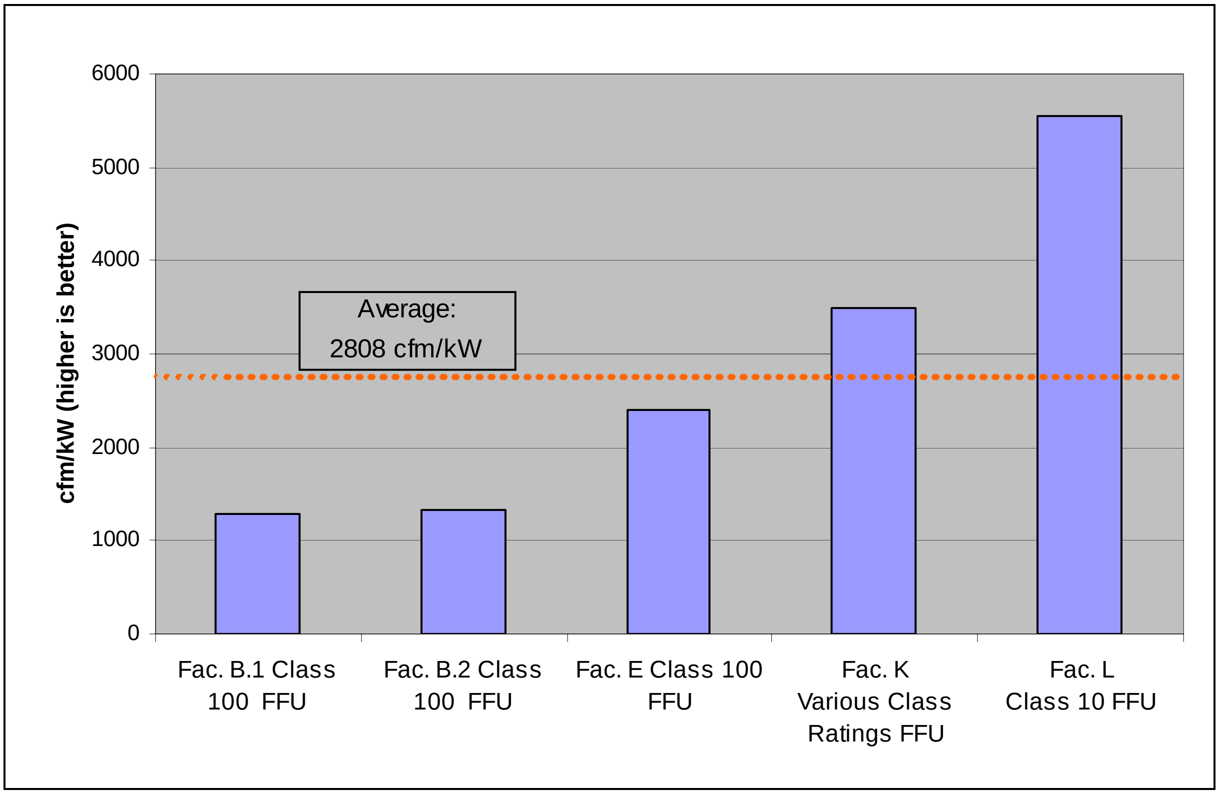


Figure 1. Fan Filter Unit Recirculation Air Handling Comparison

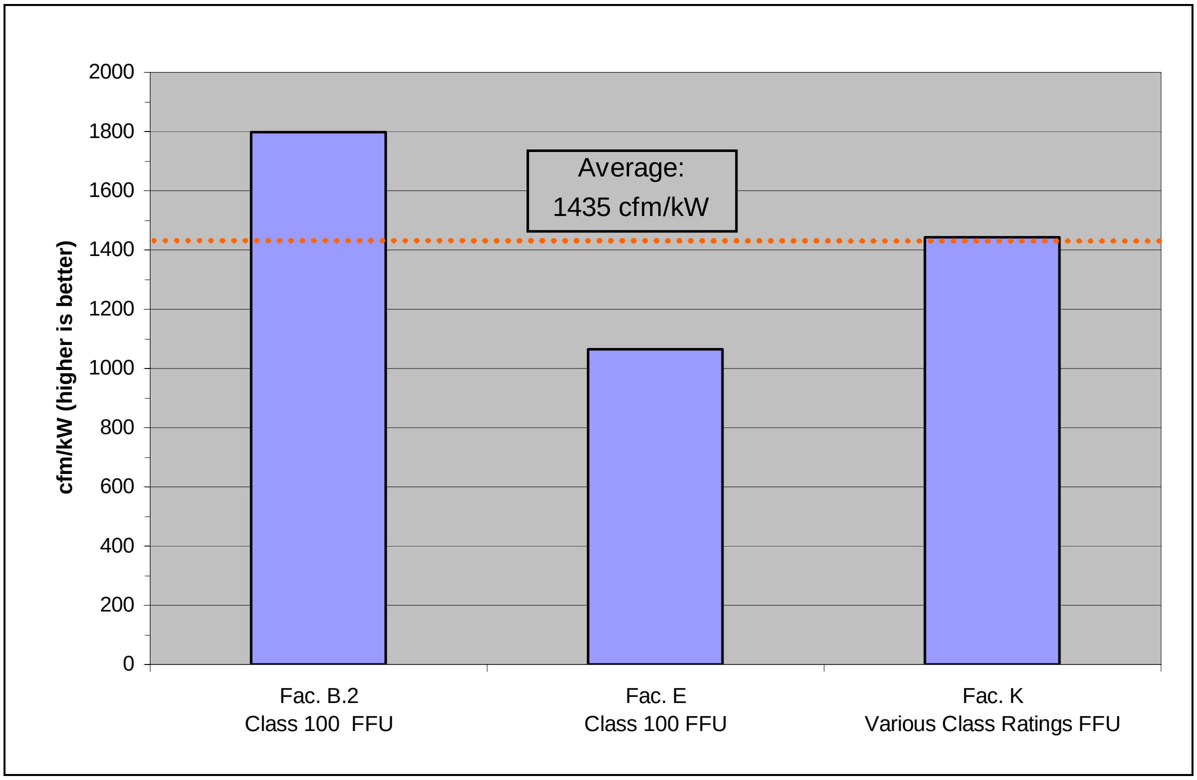


Figure 2. Makeup Air Handling Comparison

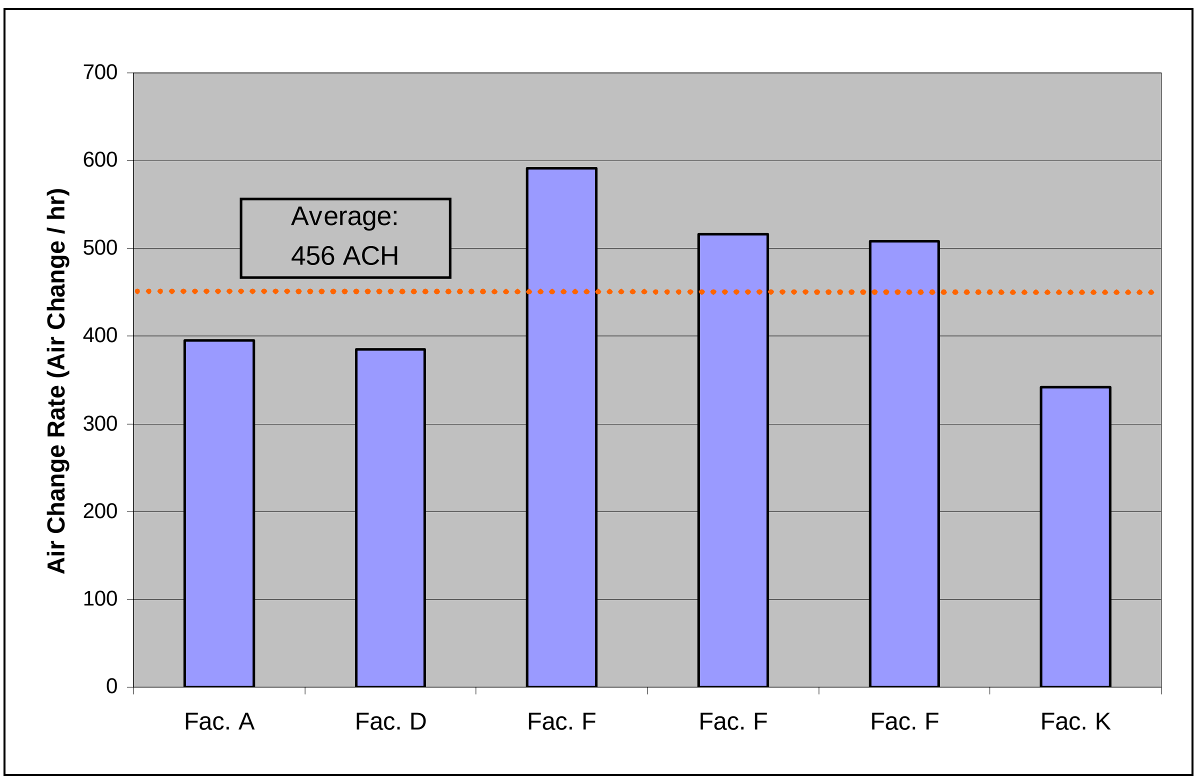


Figure 3. ISO Class 4 (class 10) Cleanroom Air Change Rate Comparison

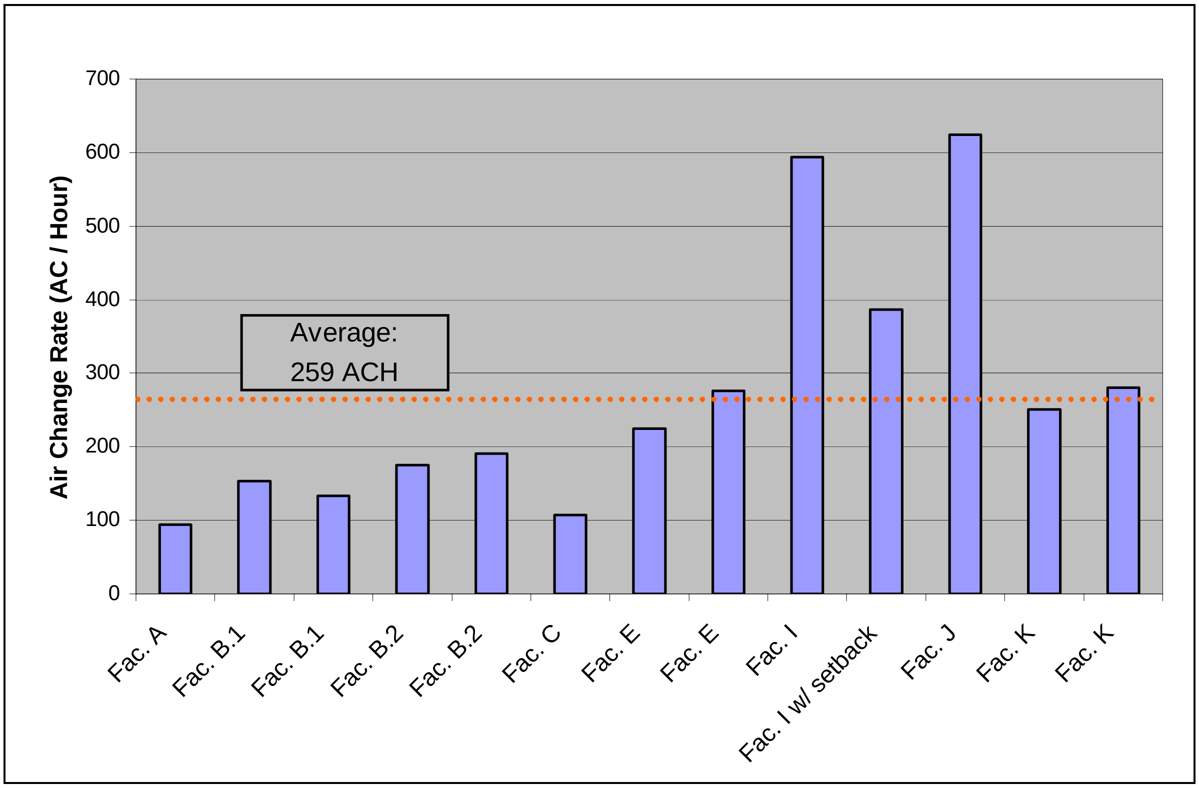


Figure 4. ISO Class 5 (class 100) Cleanroom Air Change Rate Comparison

VI. SITE OBSERVATIONS REGARDING ENERGY EFFICIENCY

Fume Hood Face Velocity

The five fume hoods in the lab area are set for a face velocity of 100 fpm with a sash height of 24". Standard laboratory practice recommends a face velocity of 100 fpm at a sash height of 18". By reducing the face area, a lower amount of airflow will need to be exhausted by each exhaust fan. The reduced airflow can be achieved by adjusting the speeds of the fan motors by changing the sheaves. This will result in fan power savings as well as cooling and heating energy savings, since less of the conditioned air will be exhausted from the space.

The cleanroom fume hoods did not indicate a face velocity. However, the face velocity should be checked and set to 100 fpm at a sash height of 18".

Vacuum Pump Exhaust

In the lab area are two vacuum pumps, which are each loosely connected to the general exhaust fan by 6" flexible ducts. The exhaust port on the vacuum pump is about 1" in diameter. The 6" flexible duct ports should be closed off with a damper, so a smaller tube can be connected to each vacuum pump and exhausted into a close by fume hood. As a result, a lower amount of air will be removed from the space, which will result in fan energy and cooling/heating energy savings.

Vacuum pumps have dramatically improved energy efficiency recently. Efficiency of new models compared to those in use should be investigated to determine pay back time. This may be eligible for a utility incentive as well.

HEPA Recirculation Hood

The HEPA recirculation hood should be turned off when not in use. A staff member indicated that the recirculation hood runs 24 hours a day. A simple modification will need to be made to the hood, which would be to add a toggle switch so the unit can be turned on when in use.

Various Process Equipment Tools

There were a couple of large process equipment tools located in the lab and cleanroom areas, which were off during the study. However, a constant volume of exhaust was being drawn from the space through the tool. An interlocked damper in the exhaust duct, which opens and closes when the machine turns on and off will lower the amount of exhaust fan energy use and the conditioned air exhausted from the space. Further energy savings can be achieved by controlling the speed of the exhaust fan with a variable frequency drive (VFD) based on a static pressure sensor located in the exhaust duct.

Demand-Controlled Filtration

LBNL is currently investigating the feasibility to implement demand-controlled filtration in the facility. Based on particle counts in the ISO class 5 (class 100) cleanrooms, the data showed that there were less than 10 particles per cubic foot of air taken at the 0.3 micron level. The cleanrooms are essentially operating at achieving ISO class 4 (class 10), which is cleaner than required. Currently, the recirculation air handling system is setback during unoccupied hours, however further setback should be possible. Demand controlled filtration (i.e. controlling based upon particle counts) should verify that additional setback is possible. By actively monitoring the particle counts in the cleanrooms and adjusting the airflow provided by the recirculation air handling system to retain cleanliness, a significant amount of energy can be saved.

Gowning Room Door Filters

The grilles in the doors located between the cleanroom gowning room and lab area space are unnecessary. This is unusual design. Removing the filters and covering up the void spaces should result in a reduction in airflow in the gowning room.

Lab Area Temperature Setpoint

The room temperature cooling setpoint is 68°F and seems low. During the warmer months a setpoint between 74 - 78°F is recommended by ASHRAE. By raising the setpoint temperature, more energy will be saved. However, if the processes in the area require 68°F then this measure will not be possible.

Fume Hood

The fume hood currently has a sign indicating that the fume hood is not working and that it should not be used. However, the fume hood exhaust fan, EF-12 is running. The exhaust fan should be turned off until the fume hood is repaired.